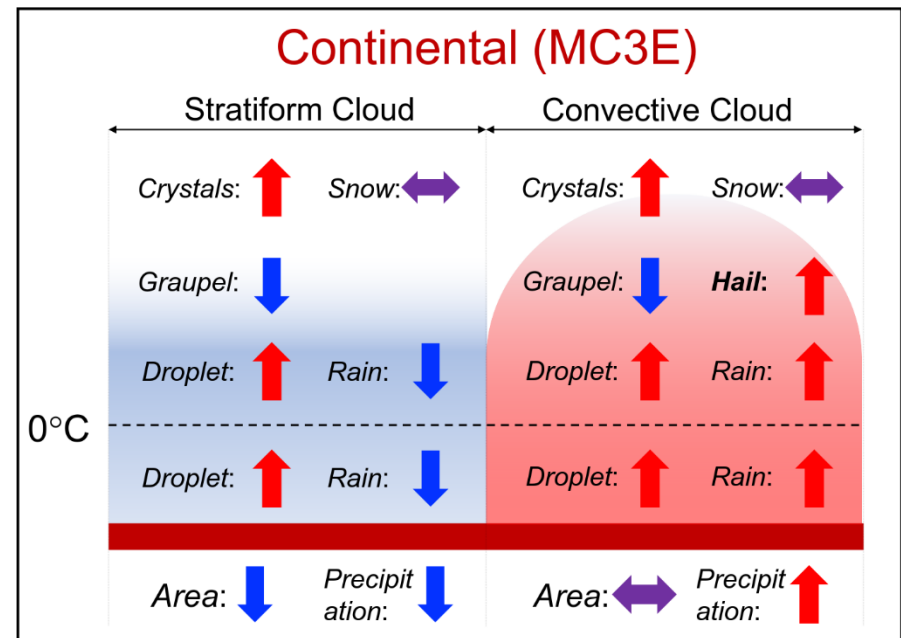
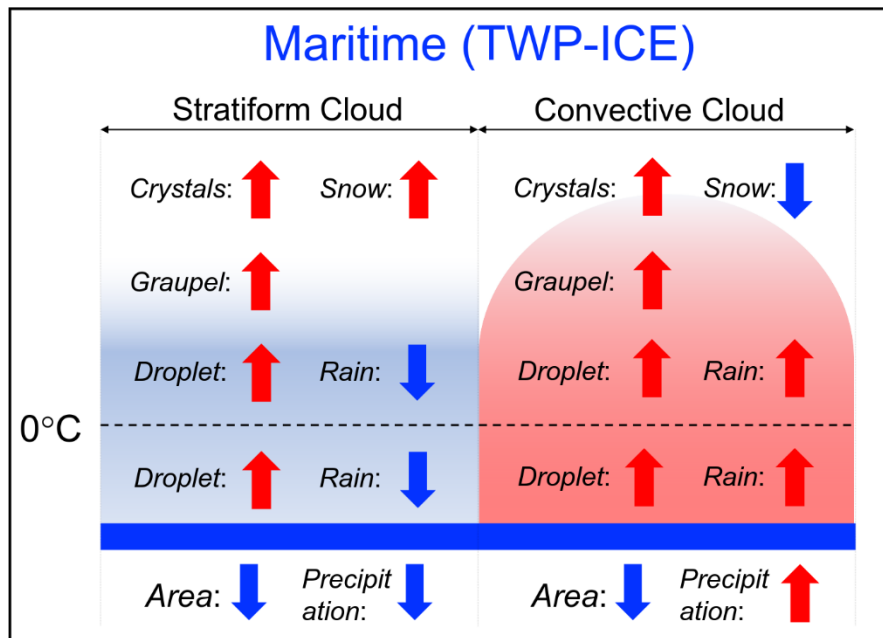


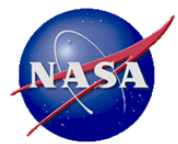
Elucidating Impacts of Aerosol and Environmental Conditions on Maritime and Continental Deep Convective Systems Using a Bin Microphysical Model



Takamichi Iguchi (Code 612, NASA/GSFC and UMD), Wei-Kuo Tao, Toshi Matsui, Stephen E. Lang; Steven A. Rutledge, Brenda Dolan, Julie Barnum (CSU)



A series of sensitivity experiments were conducted using the Weather Research and Forecasting (WRF) Model with bin cloud microphysics to investigate the effects of increase in aerosol concentration on tropical maritime and midlatitude continental deep convection systems. Increased supercooled water in polluted conditions leads to more hail and less graupel in the continental simulation. In the maritime simulation, on the other hand, enhanced supercooled cloud water promotes an increase in graupel since little or no hail is produced.



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References:

Iguchi, T., Rutledge, S. A., Tao, W.-K., Matsui, T., Dolan, B., Lang, S. E., & Barnum, J. (2020). Impacts of aerosol and environmental conditions on maritime and continental deep convective systems using a bin microphysical model. *Journal of Geophysical Research: Atmospheres*, 125, e2019JD030952. <https://doi.org/10.1029/2019JD030952>

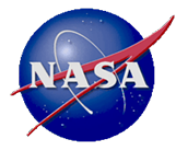
Data Sources: T. Iguchi, W.-K. Tao, T. Matsui, and S. Lang were supported by the NASA Modeling, Analysis, and Prediction (MAP) Program. This work was funded by Department of Energy (DOE) Atmospheric System Research (ASR) program (Project managers: Shaima Nasiri and Ashley Williamson) (DE-SC0014371). The computational resources were provided by two NASA High Performance Computing (HPC) facilities: NASA Center for Climate Simulation (NCCS) at Goddard Space Flight Center (GSFC) and NASA Advanced Supercomputing (NAS) Division at Ames Research Center. We made use of NASA Modern Era Retrospective analysis for Research and Applications Aerosol Reanalysis (MERRAero) as well as MERRA version 2 (MERRA-2) to conduct the WRF model simulations. The Tropical Warm Pool – International Cloud Experiment (TWP-ICE) as an intense airborne measurement campaign organized by DOE Atmospheric Radiation Measurement (ARM) in the region near Darwin, Northern Australia in early 2006. The Mid-latitude Continental Convective Clouds Experiment (MC3E) was a collaborative field measurement between DOE ARM Climate Research Facility and NASA Global Precipitation Measurement (GPM) mission Ground Validation (GV) program in central Oklahoma during the April–June 2011 period.

Technical Description of Figures:

Graphic 1: Schematic diagram summarizing the changes in various physical quantities to the increasing cloud condensation nuclei (CCN) concentration in the WRF model sensitivity experiments. The red upward (blue downward) arrows denote overall increase (decrease) in quantity with increasing modeled CCN concentrations; The purple arrows mean relatively nonmonotonic changes.

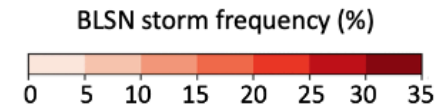
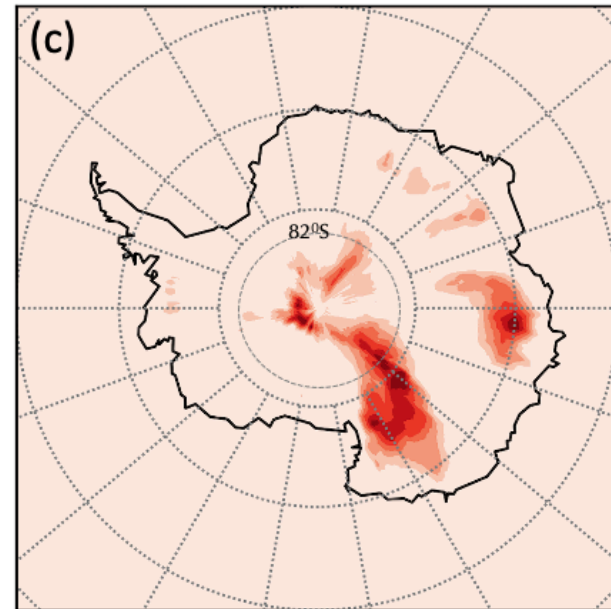
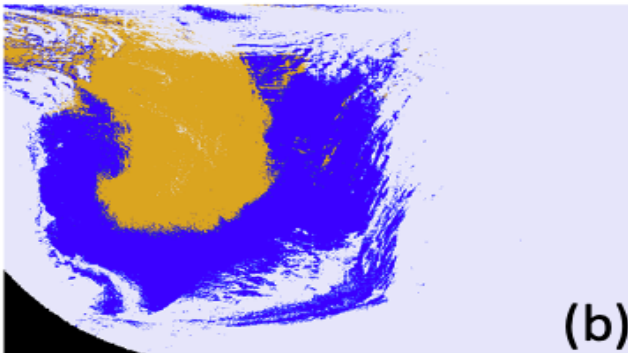
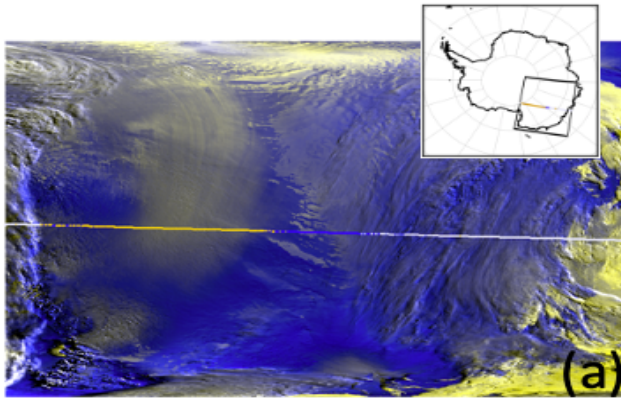
Scientific significance, societal relevance, and relationships to future missions:

The National Academies of Sciences, Engineering and Medicine (NASEM) 2017 Decadal Survey suggested the inclusion of science objectives for the Aerosol and Cloud, Convection and Precipitation (ACCP) as Designated Observables (DOs). Improving our physical understanding and model representations of cloud, precipitation and dynamical processes within deep convective storms is an overarching ACCP goal. A series of model simulations using the Weather Research and Forecasting (WRF) Model with detailed bin cloud microphysics were conducted to investigate the effects of cloud condensation nuclei (CCN) loading as well as thermodynamic condition on tropical maritime and mid-latitude continental deep convection systems. The results showed that surface precipitation rates monotonically increase with increasing CCN loading for both the maritime and continental situations, while these monotonic increases are disrupted in the simulations with reduced convective available potential energy (CAPE). The increase in precipitation is in the form of convective precipitation, at the expense of stratiform precipitation. CCN loading increases promote increases in supercooled cloud water, in agreement with previous modeling studies. However, in the simulations investigated herein, the changes in supercooled water have different impacts on the cloud microphysics in the maritime and continental simulations. Increased supercooled water contents lead to more hail (more dense and solid) and less graupel (soft and less dense) in the continental convection system. For the maritime simulation, on the other hand, enhanced supercooled cloud water contents promote an increase in graupel since little or no hail is produced. This distinction is due to the difference in relative magnitudes and peak altitudes of supercooled water and snow amounts, which is further attributable to the difference in the vertical structure of humidity and dynamics in the maritime and continental conditions.

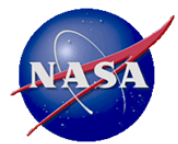


Machine Learning applied on MODIS and CALIOP observations to detect Antarctic Blowing Snow Storms

Yuekui Yang, Code 613, NASA/GSFC



Blowing Snow (BLSN) storms play an important role in Antarctic boundary layer and surface mass balance processes. To expand detection of such storms, a machine learning model was trained using observations from CALIPSO's CALIOP lidar and applied on MODIS daytime observations, extending thus coverage beyond CALIOP's narrow observation curtain and 82°S limit. MODIS then shows that BLSN storms have a large range of sizes that can reach hundreds of thousands km². The observed BLSN storm belt reveals a potential pathway of Antarctic snow transport.



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References:

Yang, Y., Anderson, A., Kiv, D., Germann, J., Fuchs, M., Palm, S., & Wang, T. (2021). Study of antarctic blowing snow storms using MODIS and CALIOP observations with a machine learning model. *Earth and Space Science*, 8, e2020EA001310. <https://doi.org/10.1029/2020EA001310>.

Data Sources:

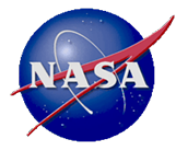
The CALIPSO Lidar Level 2 cloud layer product v4.20 used in this study can be directly downloaded at https://opendap.larc.nasa.gov/opendap/CALIPSO/LID_L2_01kmCLay-Standard-V4-20/contents.html. The CALIPSO Lidar Level 2 Antarctic blowing snow product v1.00 can be directly downloaded at https://opendap.larc.nasa.gov/opendap/CALIPSO/LID_L2_BlowingSnow_Antarctica-Standard-V1-00/contents.html. The Aqua MODIS Level 1b Collection 6.1 calibrated radiances data can be directly downloaded at <https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/6/MYD021KM/>. Funding for this study is provided by the NASA CloudSat/CALIPSO Science program; the support from the GSFC student internship program and the Office of Education is also acknowledged.

Technical Description of Figures:

(a) An Aqua MODIS granule taken over Antarctica on October 6, 2009 at 07:00 UTC. The false color image was generated with $2.1\ \mu\text{m}$ used both as Red and Green, and $0.85\ \mu\text{m}$ as Blue. The pixels along the CALIPSO track (the line in the middle) are classified as BLSN (yellow), cloudy (white) and clear (blue). The inset shows the location of the MODIS granule on the Antarctic continent; (b) segmentation results for the MODIS granule shown in (a): BLSN pixels are shown in yellow, clear in blue and cloud in white; (c) Antarctic BLSN storm frequency over the Antarctic continent for the month of October 2009. 82°S is the southernmost latitude of CALIPSO observations.

Scientific significance, societal relevance, and relationships to future missions:

BLSN storms have significant impacts on the Antarctic surface mass balance, radiation budget, and planetary boundary processes. CALIPSO has been playing an essential role in BLSN observations. However, the single pixel width of CALIPSO observations has limited our knowledge of the spatial extent of BLSN storms. This study developed a framework for BLSN storm analysis using MODIS observations. A machine learning model based on the random forest algorithm is developed for the classification of MODIS pixels into clear, cloudy and BLSN. CALIPSO observations are used as the ground truth for the training of the machine learning model. BLSN storms are identified using the classified MODIS images with the DBSCAN clustering algorithm. The framework is applied to MODIS observations during the month of October 2009. The MODIS based BLSN storm frequency map extends the CALIPSO BLSN coverage limit from 82°S to the South Pole. The BLSN storm belt from the South Pole region to the coastal area between 130°E and 160°E along the Transantarctic Mountains provides a potential pathway of snow transport. Results also show that BLSN storms have a large range of sizes, covering areas as large as hundreds of thousands km^2 . This is the first time that the spatial distribution of BLSN storms over the entire Antarctic continent is obtained from observations.



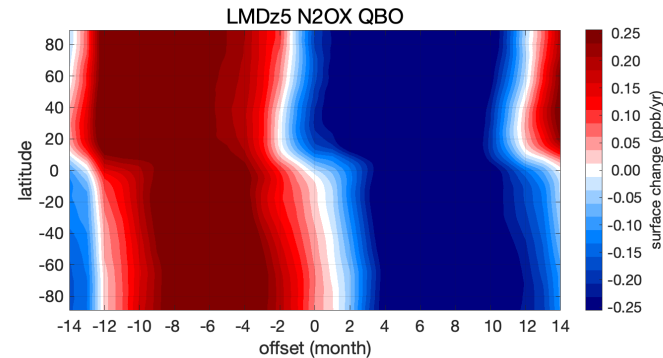
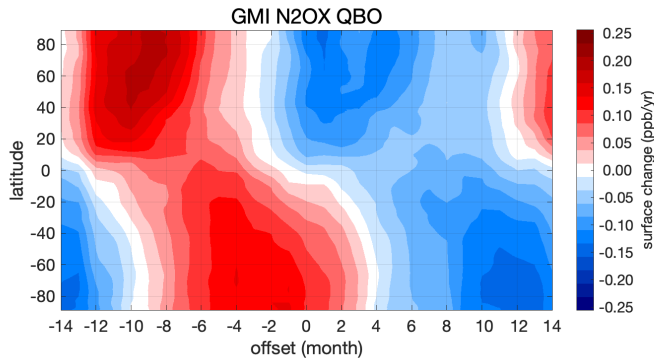
Impacts of the Quasi-Biennial Oscillation (QBO) on Surface N₂O

Daniel Ruiz¹, Michael Prather¹, Susan Strahan², Rona Thompson³, Lucien Froidevaux⁴,
And Stephen Steenrod², Code 614, ¹UC Irvine, ²NASA/GSFC, ³NILU, ⁴NASA JPL



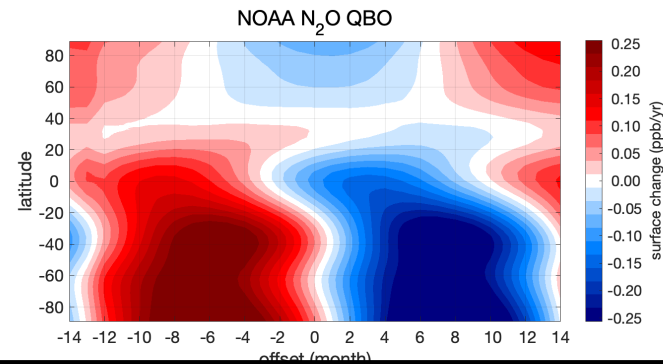
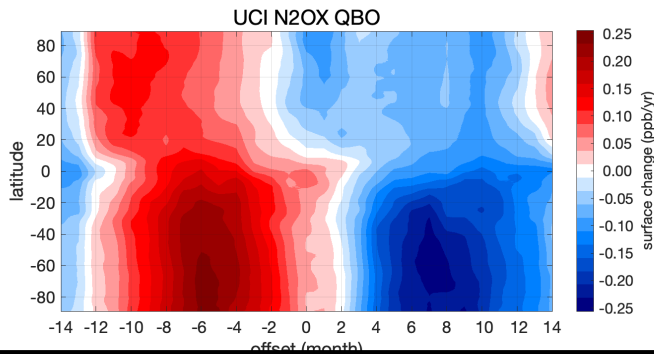
Surface N₂O change (ppb/yr over 2005-2017)

NASA Global Modeling Initiative (GMI) chemical transport model (CTM)



Laboratoire de Météorologie Dynamique, Zoom, Version 5 (LMDz5) CTM

University of California, Irvine (UCI) CTM



NOAA ESRL surface observations

- N₂O is a long-lived greenhouse gas that also depletes stratospheric ozone.
- Quantifying the variability of N₂O that is driven only by chemistry and unveils the signal caused by emissions and the human role in N₂O increase. It also provides a stringent test of stratosphere-troposphere exchange in chemistry climate models.
- A UCI study built a composite of the average QBO signal on N₂O surface variability from observations and found that multiple models reproduced this.
- Removal of the QBO signal from the observations unveiled clear observed signal of the El Nino moderations of N₂O emissions, providing more accurate quantification of natural sources.



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References:

Ruiz, D. J., Prather, M. J., Strahan, S. E., Thompson, R. L., Froidevaux, L., & Steenrod, S. D. (2021). How atmospheric chemistry and transport drive surface variability of N₂O and CFC-11. *Journal of Geophysical Research: Atmospheres*, 126, e2020JD033979. <https://doi.org/10.1029/2020JD033979>.

Data Sources: The NASA Global Modeling Initiative (GMI) chemical transport model (CTM), The University of California, Irvine (UCI) CTM, and the Laboratoire de Météorologie Dynamique, Zoom, Version 5 (LMDz5) CTM were used to simulate the N₂OX tracer for 1980-2018. The GMI CTM used MERRA-2, UCI CTM used ERA-IFS, and LMDz5 CTM used ERA-INTERIM to drive their circulations respectively. Ed Dlugokencky from NOAA ESRL provided the zonal surface N₂O data that was used here to produce an observation-based reference with which to compare our simulated results. Singapore sonde data from NASA GSFC was used to choose the synchronization point for each QBO cycle (Month zero in Graphic 1). Aura Microwave Limb Sounder N₂O and O₃ profiles were used to calculate N₂O stratospheric loss.

Technical Description of Figures:

Graphic 1: Surface N₂O change (ppb/yr) composites centered on the QBO phase transition at 40 hPa based on a rescaled tropospheric abundance of 320 ppb. Composites show the mean QBO surface impact throughout the overlap period (years 2001-2016*; six standard QBO cycles) for each respective dataset. Simulations (top panel and bottom left) are of N₂OX (zero emissions), while the NOAA ESRL observations (bottom right) are of surface N₂O (with emissions). Warmer colors indicate positive change changes with respect to a tropospheric mean abundance of 320 ppb (i.e., driven by lower loss frequencies, resulting in greater abundances of N₂OX) while cooler colors coincide with increases in loss rates. *Note: the 2010/11 anomalous QBO centered on August 2010 has been removed from these composites

Scientific significance, societal relevance, and relationships to future missions: This work takes a giant step beyond Hamilton and Fan's (2000) original modeling work where the GFDL SKYHI GCM was used with ingenious tracer experiments to show that the stratospheric quasi-biennial oscillation (QBO) produced tropospheric variability in N₂O. In the 20 years since, we have acquired observational datasets showing QBO-like variability in N₂O's stratospheric loss and also in the surface abundances. Since then, we have built more numerically accurate chemistry transport models (CTMs) and historical records of the atmospheric circulation (assimilated/analyzed wind fields) that can drive them. This work brings together 3 independent CTMs, using 3 different meteorological data sets, plus the NASA Aura satellite observations of stratospheric N₂O, and the NOAA surface measurements. We find that all the models are able to reproduce most of the variability in N₂O from the upper stratosphere down to the surface. This verification of our ability to model chemistry and transport on this scale is exciting.

- We have mapped out the average effect of the QBO over several cycles on the surface variability of N₂O. This provides a stringent and important test of the stratosphere-troposphere exchange that should be a standard metric in evaluating chemistry-climate models.
- Being able to remove the chemistry and transport signals from the observed surface record using physically based models as a baseline (instead of statistical fits) allows us to unveil the unique signal of El Nino on N₂O emissions, thus allowing more accurate inverse modeling of the anthropogenic emissions.